Advanced Technologies for Mission Operations
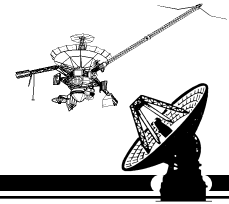
UPN 315-90-17

Walt Truszkowski, Area Manager

Semi-Annual Review of the FY97 SOMO/MO&DSD Technology Development Program

April 15, 1997

GSFC

Overall Objective

To contribute to the technology base that is required to fully support future "Lights Out" operations and the development of highly-automated and intelligent ground and space systems.

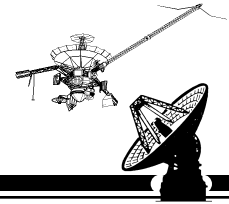| Goals	Significance
1. Establish an agent-based foundation for the development of highly-automated ground and space systems.	Agent-based technologies will significantly enhance our ability to realize true "Lights Out" operations and the associated personnel reductions.
2.. Develop a workable model-based reasoning capability for use in highly-automated ground/space systems.	Model-based reasoning will significantly contribute to the rigorous detection, correction and explanation of anomalies by automated systems.
3. Develop advanced data/information visualization techniques.	Advanced data/information visualization will provide the required interface for operator intervention in lights out operations.

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MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE
Advanced Technologies for Mission Operations
Objectives and Significance

GSFC

AGENTS
Overall Objective

To establish a core competency in agent-based technologies and support the automation of highly-complex "lights out" mission operations systems through the application of agent technologies.

Goals

1. Develop an Agent model and a Multi-Agent System (MAS) concept applicable to automated ground/ space systems.

2.. Develop and evaluate prototype applications within an integrated "lights-out" technologies testbed.

3. Formalize the Agent and MAS concepts.

4. Develop and execute a plan for technology transfer into operations.

Significance

Goals 1 and 2 are required to gain core competency in agent technology.

Goal 3 will significantly contribute to the correctness and rigor of the Agent and MAS concepts.
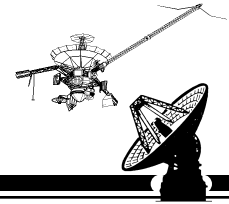
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Advanced Technologies for Mission Operations
Products and Customers

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Product	Goal #	User/Customer	Development Phase				Approach/Comments
			Concept	Design	Demo	Transfer	
Agent and MAS models development and formalization activities	1,3	in-house core competency development IMDC	■	■	■		The initial models have been evaluation and have been revised. Formalization using the Z notation has started.
User System Interface Agent (USIA)	1,2, 4	in-house core competency development IMDC	■	■	■	■	The USIA and domain-specialist agents have been incorporated into a prototype testbed and evaluated. USIA agents have also supported the SAIRE project.
Domain-specialist agents	1,2, 4	in-house core competency development IMDC	■	■	■	■	The Integrated Mission Development Center (IMDC) will utilize agents for intelligent information management activities.

Agent and MAS Model Development (Goals 1,3)
- The models of the USIA and Domain Specialist agents are being revised.
- A new agent concept paper has been developed.
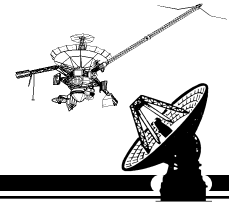- Work has begun on formalizing the agent and MAS models using the Z notation.

Agent and MAS Prototypes (Goal 2)
- The infrastructure for an integrated "Lights-out" technologies testbed called "Autonomous Mission Operations Scenario" (AMOS) has been drafted.

Faculty Advanced Research (FAR) Program (Goals 1, 3)
- Continued work with North Carolina A&T on developing program addressing formalization of agent concepts.

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FY97 Accomplishments
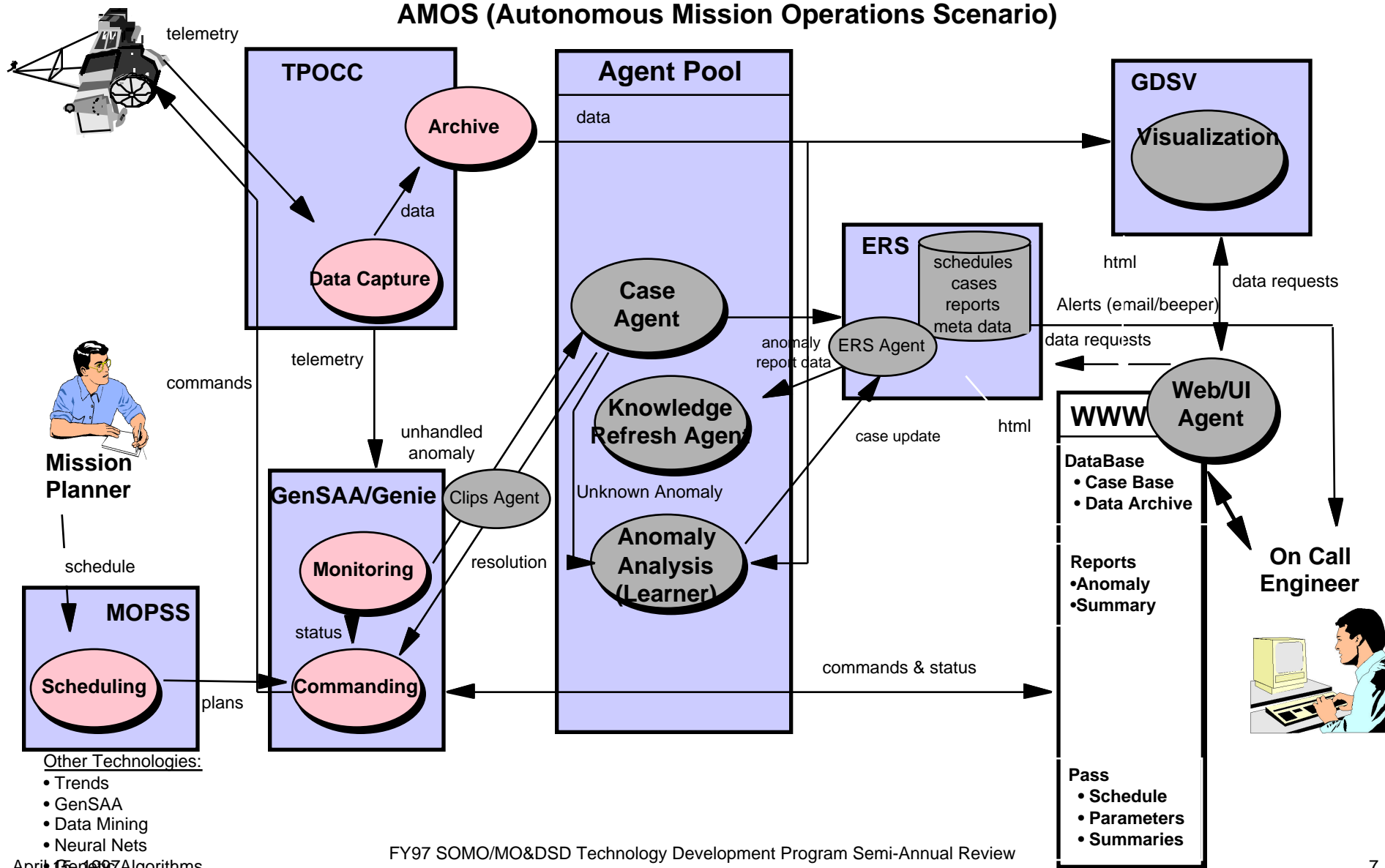
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Support for technology transfer (Goal 4)

- An Agent Technology Web page has been established. The URL is: http://groucho.gsfc.nasa.gov/agents.
- Have initiated work on the application of agent technology to support some of the information management functions associated with the Integrated Mission Development Center (IMDC) at GSFC. The agents will be applied to report generation functions and the configuration and management of a "Flatsat" testbed that will be used to evaluate proposed satellite system configurations (both hardware and software).
- Developed tutorial introduction to agent concepts (available at our agent technology web site - http://groucho.gsfc.nasa.gov/agents).
- Gave presentation at the Goddard Lights-out Conference on the implications of using agent technology for ground-based systems automation on remotely-located analysts.

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AMOS (Autonomous Mission Operations Scenario)

telemetry

TPOCC

Archive

data

Data Capture

Agent Pool

data

GDSV

Visualization

ERS

schedules
cases
reports
meta data

html

data requests

Case Agent

anomaly report data

ERS Agent

Alerts (email/beeper)

data requests

telemetry

commands

unhandled anomaly

Knowledge Refresh Agent

case update

html

Web/UI Agent

Mission Planner

GenSAA/Genie

Clips Agent

Unknown Anomaly

WWW

DataBase
• Case Base
• Data Archive

schedule

Monitoring

resolution

Anomaly Analysis (Learner)

Reports
•Anomaly
•Summary

On Call Engineer

status

MOPSS

Scheduling

plans

Commanding

commands & status

Pass
• Schedule
• Parameters
• Summaries

Other Technologies:
• Trends
• GenSAA
• Data Mining
• Neural Nets
• Genetic Algorithms

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✓ Updated USIA and MAS models. (Goals 1, 4)
- A new agent concept paper was developed.
- This model update work is a continuing process.
✓ - Established web site.
- Developed tutorial introduction to agent concepts (available at our agent technology web site - http://groucho.gsfc.nasa.gov/agents).
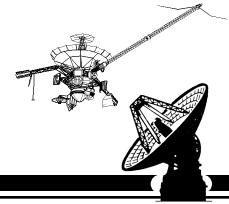
••• Development of the USIA. (Goal 2)
- work is continuing on the development of natural language interface capability to the User System Interface Agent (USIA) community.
- USIA web site established. The appropriate URL is: http://www.sem.bowiestate.edu/projects/usia/coverpage.html.

●●● Support transfer of technology into operations. (Goal 4)
- Work on this goal is continuing. The infrastructure for a "lights-out" testbed has been defined and work is commencing on its development. This testbed will provide a realistic environment in which to evaluate agent-based approaches to automated ground-based operations.

- Developed prototype agent-based applications. (Goals 2 and 4)
  - Work has begun on the transition of agent technology into the IMDC at GSFC.   The development of a detailed schedule for this work is currently underway.

- Formalize the agent concepts. (Goal 3)
  - This work is underway. An initial attempt at specifying the current agent concepts (done for us in the Z notation by a Stanford student) is being studied and updated. We are in the process of setting up a tutorial on the Z notation in conjunction with the New Jersey Institute of Technology.
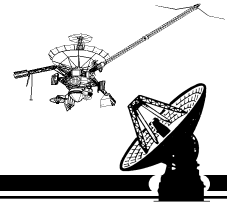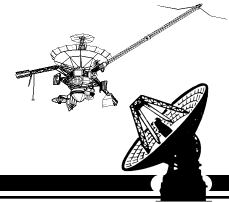
1. Continue the refinement and formalization of the agent and MAS concepts and models. (Goals 1,3)
2. Continue work on enhancing the natural language capabilities of the User System Interface Agent (USIA). (Goals 1,2)
3. Continue the design and development of a complete agent-based "lights-out" ground system testbed.   (Goals 2, 4)
4. Continue support for the transfer of agent-based technology into the IMDC. (Goals 2, 4)
5. Give presentation on agent-based mission operations at the INFORMS Conference in San Diego in May. (Goal 4)
6. Continue technical monitoring on two SBIR activities (Phase II on an agent building toolkit and a Phase I on specifications for agent communities). (Goal 4)
7. Work with a Summer Faculty Fellow on establishing agent behavior metrics. (Goals 1, 2)
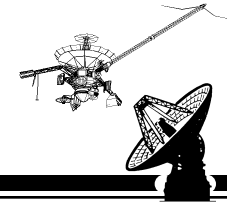
Task	FY97				FY98				FY99		FY00	FY01	FY02	FY03
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1/2	Q3/4				
Models Refinement				Model' Report ▽				Model' Report ▽	Model' Report ▽					▶
Agent formalization			Initiate ▽		Initial Report ▽									▶
AMOS testbed			Design ▽		Build 1 ▽				Build 2 ▽					▶
IMDC agent work			Plan ▽		Design ▽		Build 1 ▽				▶			
Resources by FY ($K):	120				250				250		200	150	150	

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Advanced Technologies for Mission Operations
Objectives and Significance

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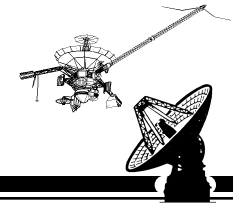
Model-based Reasoning
Trend Analysis

Goals

!. **Develop and apply model-based reasoning technology to automate routine trend analysis and assist analysts in resolving anomalies.**

- Develop model-based analysis methods for trend analysis of spacecraft systems and components.

- Investigate qualitative modeling, neural nets, genetic algorithms, possibility theory, and hybrid approaches for the interpretation of satellite telemetry.

Significance

- **Provide flight operations a new level of automation to the identification of satellite telemetry trends and the determination of possible corrective and/or preventive measures.**
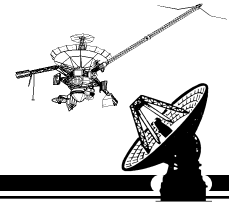
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Products and Customers

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| PRODUCT	USER/ CUSTOMER	DEVELOPMENT PHASE				APPROACH/COMMENTS
		Concept	Design	Demo	Transfer	
• Cooperative arrangement with the Spacecraft AI Lab (SAIL)	UHF FO series satellites, all future NASA missions	■				
•Trend Analysis Study Report	All projects interested in a trending capability	■	■	■	■	This report has been completed.
"TRENDS: Intelligent Model-Based Trend Analysis of Spacecraft Systems."	All projects interested in a trending capability	■	■	■		The draft of this report has been completed.

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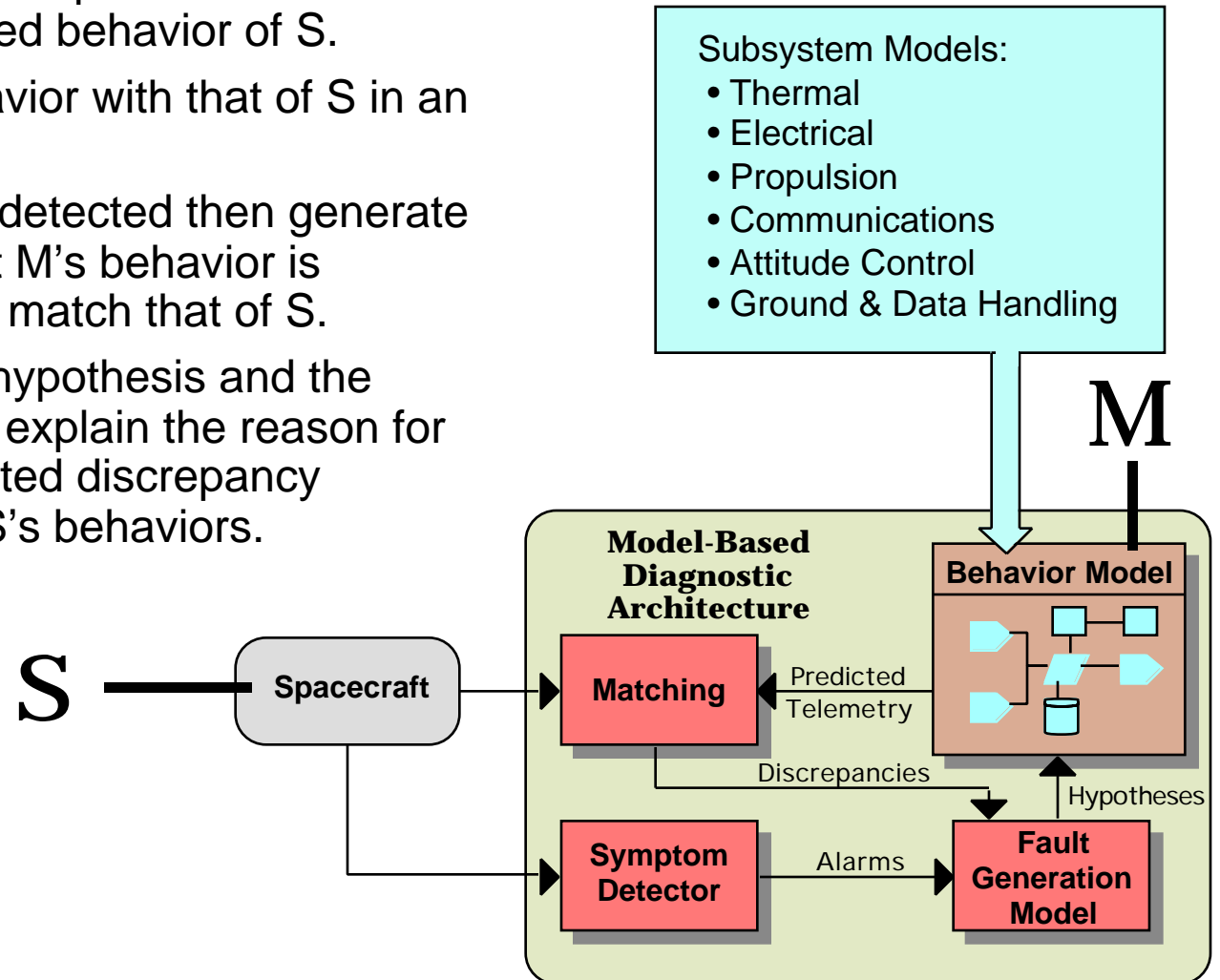### Accomplishments, FY97

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- Completed the Trend Analysis Study Report. (Goal #1)

- Initiated trend analysis work with the Naval Academy SAIL Lab and the Air Force. (Goal 1)

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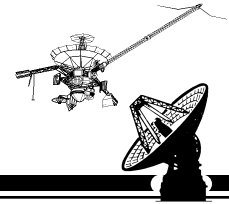**Model-Based Trend Analysis How it Works**
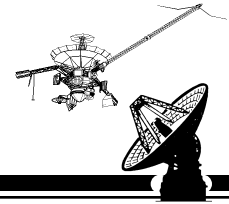
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- For a system S develop a model M that exhibits the idealized behavior of S.

- Compare M's behavior with that of S in an operational mode.

- If a discrepancy is detected then generate hypotheses so that M's behavior is modified to closely match that of S.

- Use the accepted hypothesis and the modified M to help explain the reason for the originally detected discrepancy between M's and S's behaviors.

Subsystem Models:
- Thermal
- Electrical
- Propulsion
- Communications
- Attitude Control
- Ground & Data Handling

M

Model-Based Diagnostic Architecture

Behavior Model

S ── **Spacecraft**

Matching ← Predicted Telemetry

Discrepancies

Symptom Detector → Alarms → **Fault Generation Model**

Hypotheses

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Advanced technologies for Mission Operations
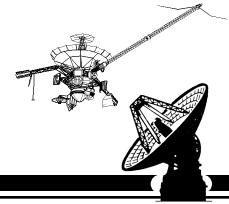### FY97 Scorecard and FY97 Plans

GSFC

●●● Research, prototyping, and evaluate trend analysis approaches including model-based reasoning, neural nets, and possibilistic analysis. (Goal #1)

●●● Set up a cooperative arrangement with the Naval Academy's Satellite Artificial Intelligence Lab (SAIL) to use their satellite subsystem models, medium fidelity simulator, and on orbit UHF FO 1 satellite as a testbed. Provide trend analysis tools to support Air Force trending activity for the UHF FO constellation of satellites.

FY97 Goals and Plans

- Continue research, prototyping, and evaluation of trend analysis approaches including model-based reasoning, case-based reasoning, neural nets, genetic algorithms, and possibilistic analysis. (Goal 1)

- Develop prototype trend analysis tools for the SAIL Lab. (Goal 1)

- Complete the "TRENDS: Intelligent Model-Based Trend Analysis of Spacecraft Systems." (Goal 1)

- Incorporate a trend analysis capability as part of the AMOS testbed activity.

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Advanced Technologies for Mission Operations
Objectives and Significance

GSFC

Data Visualization and Virtual Environments

Objectives

- First Goal: Develop and apply data visualization technologies to spacecraft ground system operations:

  - Develop the EUVE Virtual Environment for visualization of EUVE spacecraft environment including thermal characteristics.

  - Develop ground data system visualization prototypes.

Significance

- In the near future, when anomalies arise that autonomous systems cannot handle, data visualizations will empower analysts to quickly understand and focus on problems.
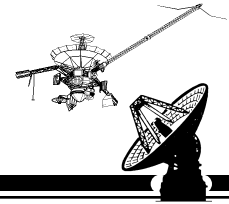
Advanced technologies for Mission Operations
Products and Customers

GSFC

| PRODUCT	USER/ CUSTOMER	DEVELOPMENT PHASE				APPROACH/COMMENTS
		Concept	Design	Demo	Transfer	
EUVE Virtual Environment	EUVE Science Operations Center (UC-Berkeley)			■	■	
Ground Data System Visualizer	target: EUVE, SAMPEX, SWAS, FAST, TRMM	■	■			

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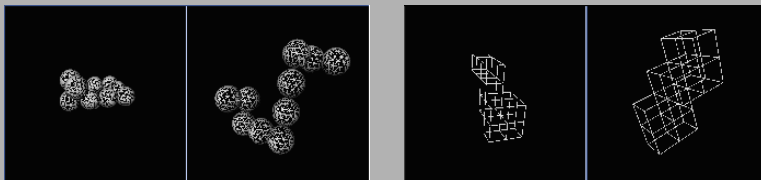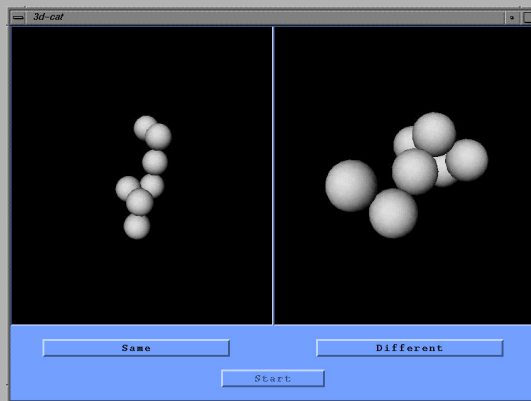### Accomplishments, FY97

GSFC

- Delivered Release 1.0 of EVE to UC-Berkeley's EUVE SOC. (Goal #1):
  - Includes thermal environment information.
  - Designed as a flexible, resuable architecture.
- Completed QuicktimeVR visualization of NASCOM control center. (Goal #1)
- Presented 3D cognitive abilities paper at SIGCHI. (Goal #1)
- Paper submitted to "International Journal of Human-Computer Studies"
- Began requirements analysis and technology evaluations for Ground System Data Visualizer.
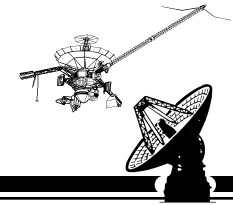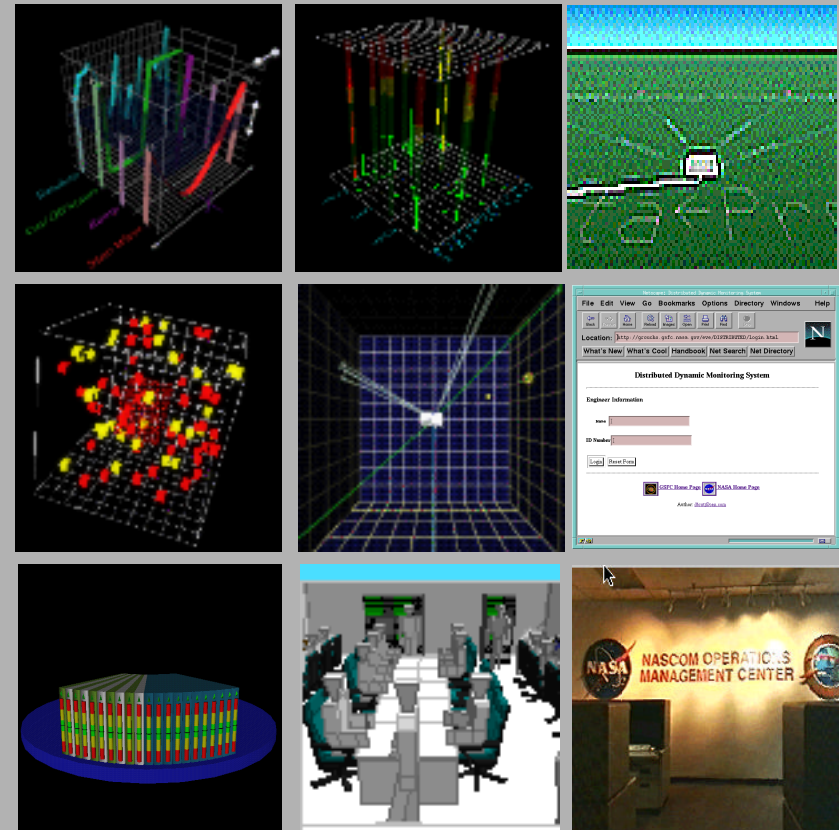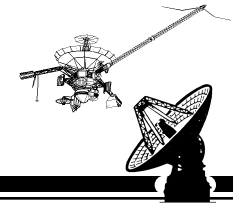
GSFC

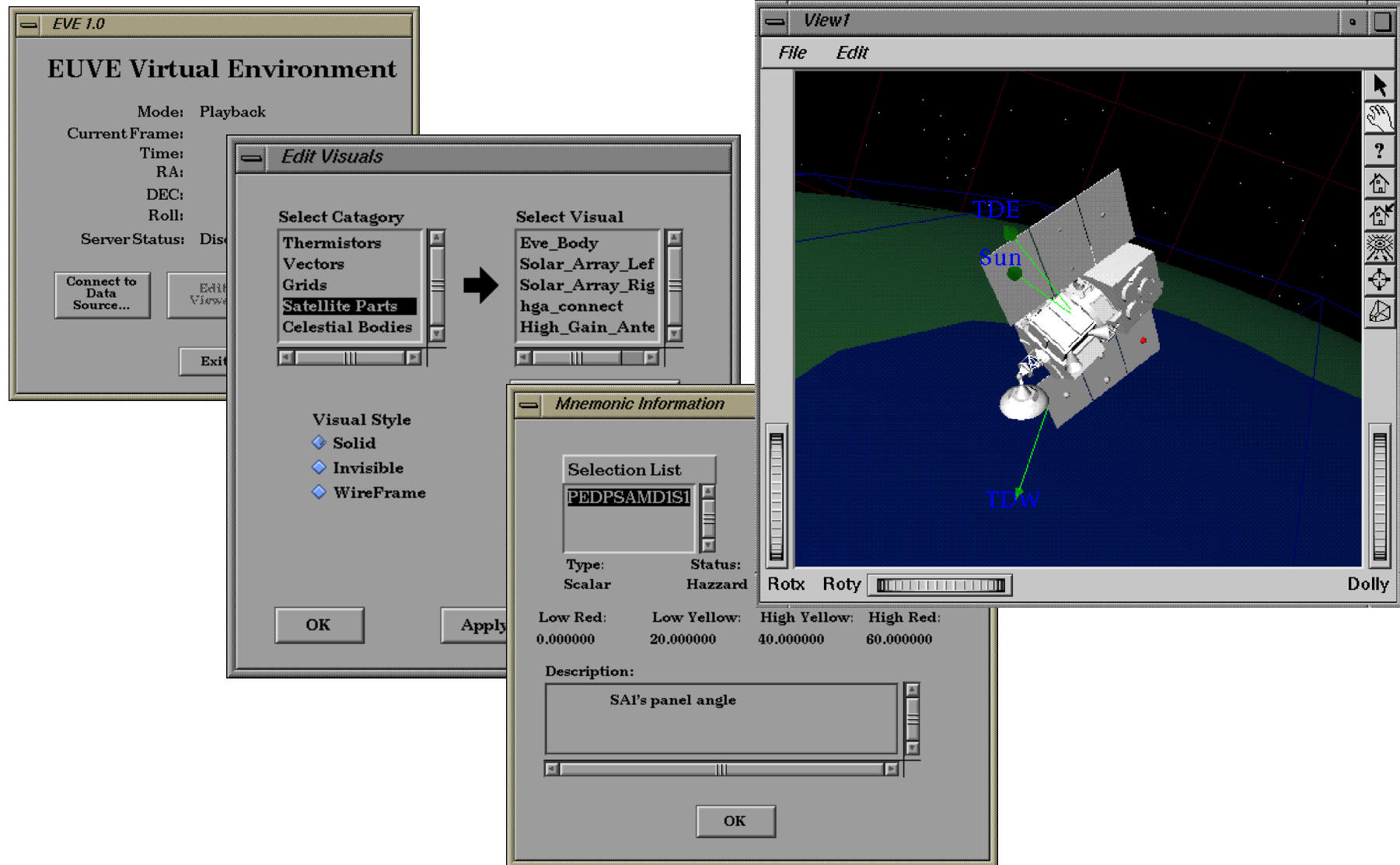# 3D Cognitive Abilities Research
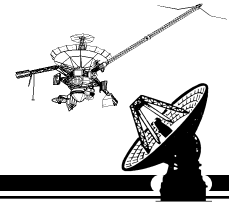

Spacecraft Ground Data Visualizations

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Advanced Technologies for Mission Operations
Accomplishments, FY97 (Cont'd)

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Advanced technologies for Mission Operations
FY96 Scorecard and FY97 Plans

GSFC

FY96 Scorecard (Goals and Status)

✓ Delivered EUVE Virtual Environment (EVE) Release 1.0.

✓ Presented 3D cognitive abilities research at SIGCHI97 conference.

••• Develop Ground Data System Visualizer prototype.

FY97 Goals and Plans

- Complete Ground Data System Visualizer prototype (9-97).
- Begin EVE Release 2.0:
  - Integrate portions of the ground data system visualizer.
  - Make displays available on the web using VRML/Java.

	FY97											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Virtual Environments • Ground Data System Visualizer prototype					▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬							
• EUVE Virtual Environment Release 1.0	▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬											
• EUVE Virtual Environment Release 2.0									▬▬▬▬▬▬▬▬▬▬▬			